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Federal Communications Commission

Comments on RM-10805, RM-10806, RM-10807, RM-10808, RM-10809, RM-10810, RM-10811 concerning Element 1 (Morse Code), Amateur Radio Service examination.

Terrence Rogers WA4BVY Extra
5205 Silkwood Drive
Durham, NC 27713
Email: terrence.rogers@att.net

Summary

- That automation is rapidly approaching human skill and reliability in transmission and reception of International Morse code rendering it no different than other digital modes for emergency use in principle.
- That Morse Code radiotelegraphy as commonly implemented is not the most efficient by any measurement nor does it exceed other methods on principle and ought not to be singled out solely for historical reasons.
- That Morse Code creates an impediment to entry into the service but without compensating benefit.
- That for simplicity and access, licensing ought not to be complicated by mode related testing requirements which in any event will become obsolete.
- That Technician (plus) class should be retained, Morse Code specific related items withdrawn and problems commonly encountered with digital modes replace it for General class and higher.
- That Radio Amateur organizations be encouraged to establish training programs for the proper use of new modes as they emerge and establish a voluntary proficiency level certificate to include Morse Code as an alternative to regulatory requirements.

Comments

Comments are grouped per subject matter. The same point is raised in several of the petitions and commented upon in one section.

That Morse Code reception is no different from other digital modes

Napurano (RM-10806) especially but also Rightsell & Kholer (RM-10807), Speroni (RM-10808) and FISTS CW Club (RM-10811) place manual CW Radiotelegraphy in a special class by itself based on its supposed reliability and simplicity stating (Napurano) that it enhances public safety. The idea is that manual reception makes it uniquely reliable and compatible under adverse operating conditions compared to digital methods. While I believe it is universally accepted that Morse radiotelegraphy is both effective and the most widely accepted digital standard, it does not follow that any particular operator needs to employ manual transmission and reception methods to be as effective even for the moment accepting that Morse is the most desirable protocol. The operator could deal with Morse the same as any other digital mode, with a Codec. The reason is that for good conditions, there are already a number of PC software programs (meaning hereafter the most common HW & OS configuration Intel & Microsoft) that are able under good conditions to copy as well as most operators and certainly able to transmit as good as the best since it is essentially perfect. In the past (1985), I was able to create a system using a hardware filter and software combination on the now ancient, slow (4 MHz) and small Commodore 64 that could copy under fair conditions. More sophisticated filters can now be implemented in software and it

would be possible to correct the problems I saw then such as adapting to operator "swing" using data base techniques similar to but simpler than those now common in word processors for auto complete and syntax checking. Such software now could run on small battery powered pocket or portable PCs requiring no extra hardware or even using the processor integral to many of the newer transceivers. If external, cost can be less than 1/5th that of a typical HF transceiver. Systems equivalent to a human are not yet common but I believe they are currently possible at low cost and small size.

An argument is that such an automatic Morse system is more complex and less reliable than a straight key and ear, which it is but the argument is moot because the transceiver itself is a complex, computer controlled system. An observation is that the first Morse systems were automatic transmission and printing systems. Morse himself preferred automation which is now both practical and equivalent to most operators.

Morse radiotelegraphy is unique only in its history.

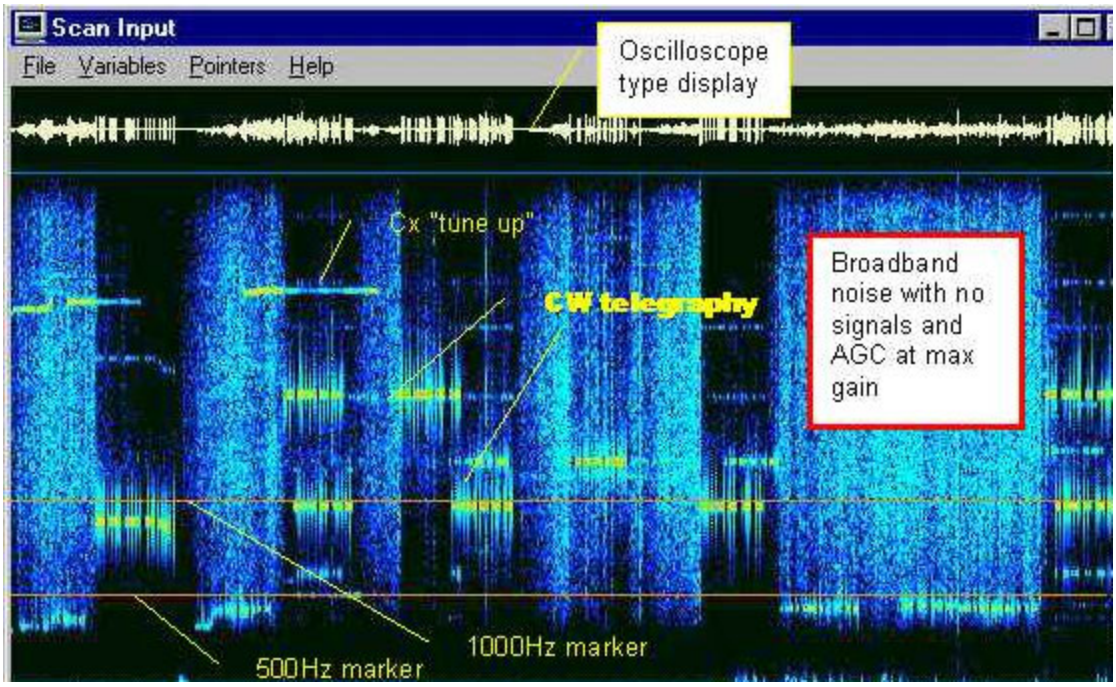
That Morse Code as implemented is not the most efficient

Napurano (RM-10806) uniquely makes the argument that Morse radiotelegraphy is "the purest, most accurate, efficient, reliable and economical form of radio communications ever devised." This was a true statement when I was in college in the 1960s but no more. I was part of a team at Ericsson Amateur Radio clubs (there are several placed around the world) using W4EUS and W5EUS, which performed a series of tests over a number of days on HF bands comparing the accuracy and power efficiency of digital modes using available software. We compared digital modes against Morse radiotelegraphy. We found that modes like MFSK using incoherent detection and Viterbi forward correction codes could easily surpass most Morse operators and was at least equal to the best Morse operators. Further, we found that human operators performed as if they possessed a filter about 200Hz wide which we latter found to be an approximation of human capabilities at near 1 kHz in the psychophysical noise masking phenomenon. If one accepts this theory, then from first principles humans cannot equal the efficiency of low baud rate systems like PSK31 in what is know as flat fading environment owing to an overly wide natural filter and conflicts with narrow electronic filters. In a Doppler multipath fading environment, human performance is not as good as even the current available systems like MFSK16 since this system adds both redundancy and interleaving to combat the loss of any single frequency or symbol. Other systems such as MT63 offer similar promise but with available software we found they were not as good as MFSK at the present time but could be improved. Both MFSK and MT63 have some characteristics similar to OQFDM which was selected for digital FM broadcasting in the US and offer similar performance.

Investigating further, we found that in heavy multipath fading, the narrow information channel of Morse radiotelegraphy was sometimes working against it. Doppler offset in one or more of the paths causes a null to pass through all frequencies at a quasi-constant rate and this would periodically eliminate the Morse signal which possessed no redundancy to recover. Operator's frequently guessed wrong say changing "look up" to "lock up" which might make as much sense. Formal methods such as those used in Amateur Radio traffic handling for many years can somewhat counter the problem but do not locate the problem mentioned above since word count is the same. Such errors are at least reliably flagged by digital systems.

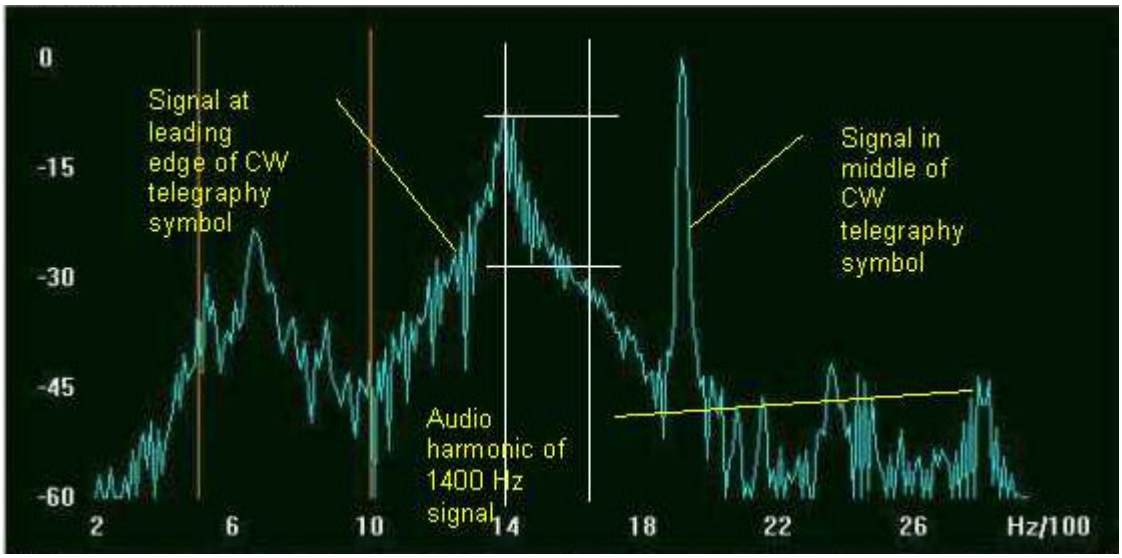
Investigating further, we found that although potentially Morse radiotelegraphy could be spectrally efficient, in practice it was not as compared to the most common HF Amateur digital modes. Two time = left to right *waterfall* type spectral prints are shown below. The first two are recordings of a 3 kHz portion of the 20 meter band during a contest. Conditions were good with minimal fading. Morse signals are marked *CW telegraphy*. Broad bands of noise are seen when all strong signals are absent and receiver AGC recovers. Black is no, blue is weak, cyan is strong and yellow is very strong spectral component. 500Hz and 1 kHz markers give a sense of scale. CW (AM) Morse Telegraphy signals are seen to occupy about 500Hz in practice although there is a

peak concentration in a narrow band less than 50 Hz wide. Nevertheless, these side bands cannot be ignored. Signals can be seen to be spaced about 500Hz, a common practice.



Waterfall Diagram of CW Signals on 20 meters

Below is an *oscilloscope* type spectral diagram made of the same band at about the same time.



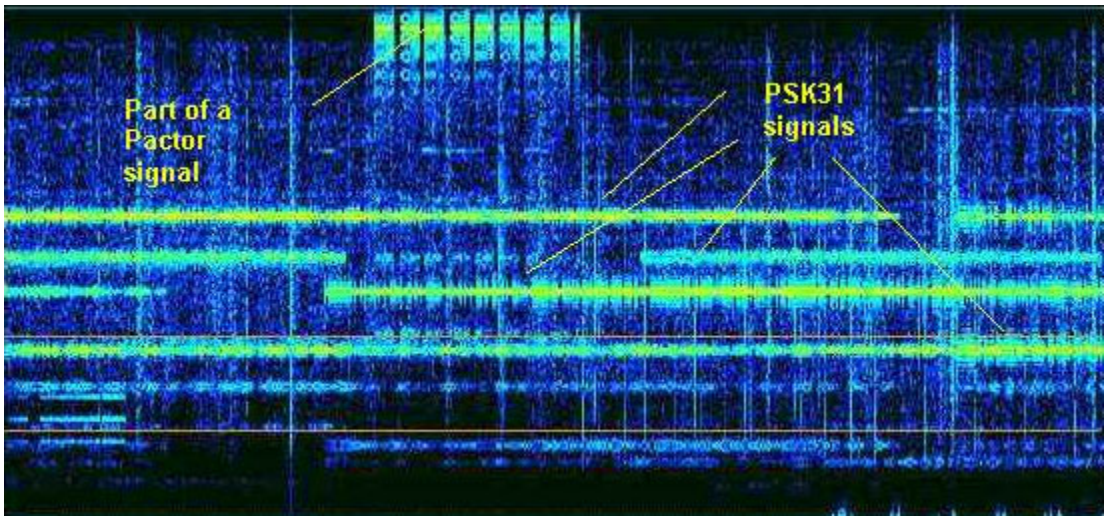
Oscilloscope Type Spectral Diagram of CW Signals on 20 meters

Experienced operators recognize the 500+Hz wide spectrum as *key clicks*. Some transceivers, such as those from Ten Tec, have an adjustable key click filter but it is rarely altered to match speed and is in any event, just a simple one pole filter (as is clear above) applied in many cases to a non-linear transfer function portion of the transmitter. Thus each CW signal transitions between wide and narrow form as shown and for the reasons shown above at the close and open

of the keyer. This action cannot be seen in a static picture. A signal 60dB down cannot be placed within 600Hz without suffering some errors due to key clicks. Higher code speeds cause more errors.

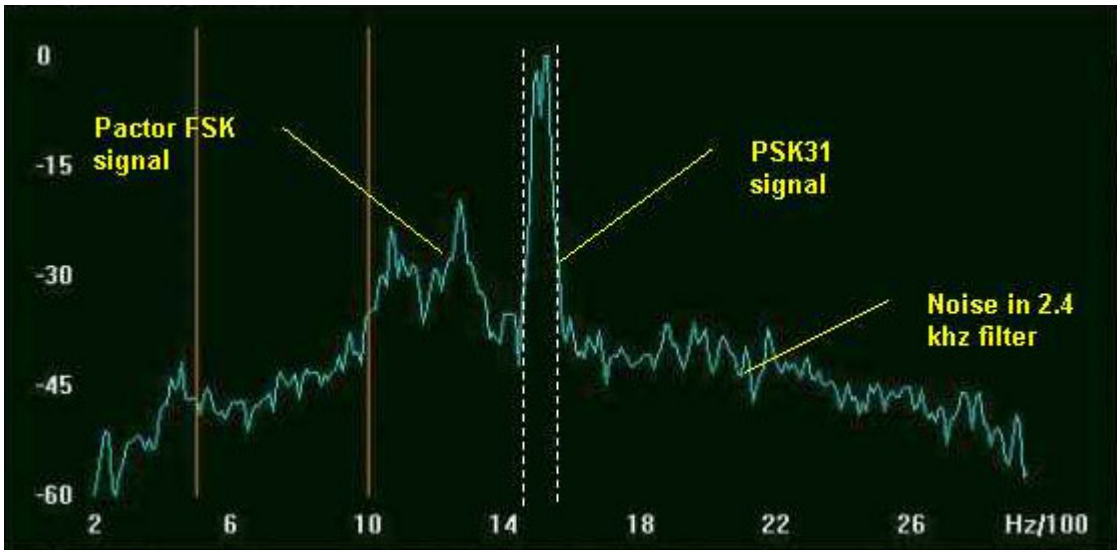
Another practical limitation is that of available receiver filters coupled with human performance. Many transceivers have no filters narrower than 500Hz which is a factor leading to 500Hz intrinsic spacing. Some transceivers have 250Hz or even narrower filters (especially DSP enabled units) but even these are most often designed for maximum selectivity giving no thought to time domain performance. That leads to *ringing* which irritates humans at higher speed since they cannot employ synchronous symbol sample point methods as do digital systems and require that the signal fall more than 30dB down to be considered rapidly switched off (from abstracts in the *Engineering Compendium*, a psychophysical reference).

In contrast, the 20 meter digital mode band in that occupied most often by PSK31 signals (which are 31 baud BPSK) looked like that below at about the same time.



Waterfall Diagram of 20 meter PSK31 signals

These signals are in the same color coding, 60Hz to 100Hz wide (the wide signal is referenced in a comment below) and they are intrinsically spaced about 200Hz apart (under ideal but crowded conditions, this drops to ~100Hz). Signal shaping occurs at a point where linear amplitude control is possible. The specified time domain filter leads to a signal about 30dB down at 60Hz wide and 60dB down at 180Hz wide. 100Hz spacing permits 40db dynamic range. Below is an on air oscilloscope spectral diagram of a PSK31 signal.



Oscilloscope Type PSK31 (BPSK 31 baud) Signal on 20 meters

The PSK31 signal can be seen to be about 100Hz wide at 35dB down which is consistent with the specified PSK keying filter laced with some transceiver phase noise.

Note that the PSK31 signal maintains this small width even when Viterbi forward error correction is added at ~50WPM and provides very good copy under weak signal conditions when a skilled operator using the same transceiver cannot exceed 10 to 15 WPM. It is, however, subject to the same multipath fading limitation as CW and to a greater degree as implemented (note that digital cellular phone defeats multipath using an equalizer which is not commonly used in Amateur Radio). An improvement called PSK63 is available. As stated above, expanding to approximately 300Hz using MFSK16 effectively combats the multipath problem without resorting to computationally intensive equalizers (which are not effective when a narrow signal disappears anyway). Not shown is another study which shows that multipath nulls are typically narrow enough that both MFSK and MT63 500 Hz modes survive.

Thus either considering S/N (power efficiency especially energy per symbol to noise density ratio) or speed or spectral efficiency or resistance to multipath fading, manual Morse radiotelegraphy as actually practiced is inferior to digital modes already widely employed. Further, the PSK31 protocol is so widely deployed that it forms a de facto digital standard for emergency use.

Ironically, truly narrow Morse Code is generated by software for PSK31 and other digital modes when the CW ID option is enabled. The signal is passed through the same effective digital filter as the digital mode signal. However, it seems a contradiction to require SW for other digital modes in order to produce spectrally efficient Morse signal which method in any event is not widely used except in Morse Codec SW.

That Morse Code creates an impediment without benefit

I was one of the first volunteer examiners and have been the instructor or coordinator for many entry level radio amateur educational classes. Even when the prospects are nearly all professional communications engineers having been part of teams for many products certified by the FCC and other worldwide regulatory organizations, only about half option for radiotelegraphy and only half of those complete the course at 5WPM which speed is not useful. The great majority of those entering Amateur Radio do so with the no code license as shown by the FCC's own data base statistics (http://ah0a.org/FCC/New.html). My students dislike the Morse requirement and engineers especially see no point in it. On the other hand, when I give talks at

Amateur Radio clubs, I find the majority in favor of continued Morse requirement. When I explore that further, I find that either they are under the mistaken impression that there is something intrinsically superior to Morse radiotelegraphy as compared to digital modes or as often that they understand it is an impediment to entry and desire it to be that way. Sometimes they say they like the exclusive club nature of the Amateur fraternity created by Morse (ignoring half the club which has only a no code license). Sometimes they say that code was difficult for them and should be for others (snob factor) and sometimes they say that this impediment helps to *weed out* trouble makers. Alas, to the last point, I was involved in the development of a digital scanning antenna (DoppleScAnt) which is often used to find trouble makers on local two meter repeaters. Whenever I have been involved with these searches, we more often than not find a licensed radio amateur with full code capability. Again, this is born out by the FCC's own statistics. If anything, the Morse Code requirement seems to attract trouble makers who resent the proliferation of newer modes.

At one time Morse Code requirement was a necessity, then a nicety. Now it's a liability.

That licensing structure ought not to be complicated

Rightsell and Kohler (RM-10807) and Speroni (RM-10808) would require a menu of options for licensing in effect creating many new classes of license (Speroni). This is contrary to the trend already established by the FCC and directed by Congress, that regulation be minimized. It also adds a burden on the volunteer examiners who in the extreme case (Speroni) would need to have many new elements for new modes. There is also the added burden for the FCC to sufficiently categorize these modes for the various classes. It's also contrary to one of the purposes of Amateur Radio, to encourage experimentation. And who could say what class a new mode might fall into (say for example digital voice with optional data transmission and picture capability)? The general trend is one the communications industry calls *convergence*. That is, all communications tends towards a single digital transmission protocol class in which case the signal is simply a *byte pipe* where the only distinguishing characteristic between various modes would be baud rate or not even that. HF broadcasting is entering a digital mode transition even now and US FM broadcasting soon. US TV is already transitioning. It is well known amongst communications engineers that a single design, that of the IQ modulator, can generate all digital modes and that a single equivalent receiver topology can decode all digital modes at least in principle changing only the base band digital filtering and symbol detection (frequently all software). I can see no basis for complicating the license structure based upon modes which should soon converge in any event.

That Technician Class ought to be retained and not promoted

Young (RM-10805) would give some HF SSB privileges to Technician class without code. Technician plus, of course, already have some 10 meter privileges and there seems to be no real problem in that. However, this band is not often open and is expansive. Further, more complicated multipath propagation modes are not as often seen here and there is less likelihood for interference in shared bands. The technician written class exam is lacking in exactly this area, HF modes. I would not be opposed to additional SSB privileges in bands at or above 21 MHz which are similar to 10 meters but do not support extension to lower frequencies.

That responsibility for Morse Code and Digital Mode proficiency should be left to Radio Amateurs with Caveat

Amateur Radio deals of course with FCC regulations but it has its own history and traditions that fall outside the province of the government. Morse Code should now be added to that list. It need not disappear. To ease transition into a *No Morse Code* environment, the FCC could encourage or require that VECs continue to offer the Morse Code exam at speeds they deem appropriate and issue certification which they would maintain in their own system having no official status but that would be readily available to the public, perhaps over the internet and in

conjunction with call book servers. Thus the VECs would require volunteer examiners to be proficient in Morse Code but that would be the only quasi official requirement. Thus pride and tradition can be served without requiring Morse Code for a license. It has also been my experience that Morse Codecs used consistently actually train operators without deliberate effort. It was in this way that I managed for a time to achieve 50WPM starting from 30WPM where I am again today. I had several students use this method as well beginning at zero. So permission to use and promotion of SW Morse Codecs train Morse operators even against their will. It may paradoxically turn out that the lack of a Morse requirement will generate the largest possible reserve of trained Morse operators. Such things can be left to the national clubs and VECs with the FCC's encouragement.

Several petitioners have asked for more rigor in the exam (PRARL RM-10809, FISTS CW RM-10811) especially for digital modes (FISTS). In this I agree but only to a point. My opinion of the FCC rules and exam requirements is that they are written to require knowledge which provides for minimal accidental interference, safety and responsibilities to keep the FCC appraised of activity should you desire to know. There is nothing in there to promote a happy experience or success communicating. That is the accepted responsibility of the Amateur Fraternity especially in the national clubs and of Amateurs acting individually. That should continue, perhaps expressed in a more formal manner. However, a class of digital modes, those with varying envelopes, require special attention to linear transceiver operation the same as a number of PCS and other modes. Radio Amateurs must achieve adequate linearity for good spectral performance without sophisticated equipment. Despite insistent warnings in the SW Codecs and Suites distributed for such modes, a large portion of beginners, perhaps as much as one quarter, experience difficulty adapting and adjusting their equipment. There was a similar state of affairs in the 1950s at the introduction of SSB which has been reflected in the exams. There are sufficient differences in the use of these digital modes compared to SSB, at least in the interim while external Codecs are required, that I believe the rigor suggested especially by FISTS should be implemented to the degree that it is generic and leads to a reduction of interference for all digital modes. That said, I note that almost all operators are helped to better operation by those already on the air.

Personal Background

- Licensed Radio Amateur beginning 1958 WV/A2BFP now WA4BVY. QCWA, Amateur Extra license #92 (ENY) in 1961
- Used CW Morse Code Radiotelegraphy heavily for many years. ARRL certificate at 30WPM and attained peak 50WPM reception by ear
- Military long range radio operator in Viet Nam including manual radio telegraphy
- One of the first volunteer examiners
- Club presentations and Radio Amateur publications (ARRL QST 1978 DoppleScAnt digital scanning antenna)
- Digital mode usage beginning RTTY FSK in 1963 and continuing on up through present with BPSK, QPSK, MFSK, FSK packet and simplex TTY
- Wrote software for automatic Morse Code reception beginning in 1984.
- Graduate physicist and engineer, licensed to practice Professional Engineer in North Carolina
- Thirty years experience design of commercial and military communications systems analog and digital and presently systems engineer for digital cellular phones. A number of patents in communications systems with continuing applications.

Abstract of Petitions Commented Upon

This section is only for completeness. Commission personnel are no doubt very familiar with these petitions and need not read any below. Abstracts from ARRL bulletin ARLB061.

RM-10805 Retain Element 1 but Give some HF SSB to Technician

Charles L. Young Jr, AG4YO, asks the FCC to delete the 5 WPM Morse code test (Element 1) for Technician-plus-Element 1 privileges (formerly "Tech Plus"). His petition would retain Element 1 as an examination requirement for General and Amateur Extra applicants and give Technicians limited HF SSB privileges.

RM-10806 Retain Element 1 for Public Safety

Describing CW as "the purest, most accurate, efficient, reliable and economical form of radio communications ever devised," Frank Napurano, K2OKA, requests that the FCC retain the 5 WPM Morse requirement "in the interest of public safety, the preservation of a radio art and as a tribute of support for a prized and respected avocation."

RM-10807 Retain Morse Code as Exam Questions for Points

A petition by Robert G. Rightsell, AE4FA and Harry A.M. Kholer, N0PU, would continue Morse testing but give applicants up to 24 points of exam credit according to their success on Element 1. The final exam score would be the sum of earned Element 1 points and the written test score for a possible total of 100 points. Their petition also calls on the FCC to consolidate the Novice and Technician and the Advanced and Amateur Extra licenses, boost the number and range of written test questions and give new Technicians CW and data privileges.

RM-10808 Retain Element 1 but Only for Code Mode Privilege

Joseph Speroni, AH0A, seeks to have the FCC delete Element 1 for applicants who want to operate phone on HF but retain Element 1 at 5 WPM for applicants who want to operate CW. His petition would restructure the Amateur Radio testing regime to require specific knowledge of "RTTY, data, image, spread spectrum, pulse/test, RACES/ARES and space communications only for those wishing to operate these modes." Under Speroni's plan, applicants would be under no obligation to pass mode-specific examination elements for mode privileges they don't wish to operate.

RM-10809 Delete Element 1 but Increase Vigor of Remaining

The Puerto Rico Amateur Radio League (PRARL) asks the FCC to delete Element 1 for Technician and General classes but to increase the rigor of the written elements for those two license classes. The PRARL would keep the 5 WPM Morse exam for Extra applicants. The PRARL also would eliminate same-session retesting and require 30 days between retakes.

RM-10810 Simplify Licensing but Retain Morse Code for Amateur Extra

James Roux, W4YA, proposes in his petition that the FCC cut the number of license classes to two--General and Amateur Extra--and the number of written examination elements to one--at the General level. Roux's petition would eliminate the 5 WPM Morse code exam for General but require Extra applicants to pass a 15 WPM test. Roux also would give Generals all currently available amateur privileges except the Extra-class CW sub-bands.

RM-10811 Retain Element 1 and Add Testing Vigor

A petition filed on behalf of FISTS CW Club would delete the requirement to pass Element 1 to obtain Technician plus Element 1 (ie, "Tech Plus") HF privileges. It would merge Tech and Tech Plus into a single class, emphasize technical content, including digital modes, on written examinations and extend digital mode privileges within Novice/Tech Plus subbands. It would not provide additional HF phone privileges for Technicians, however. The FISTS petition would retain a 5 WPM Morse exam for General applicants and raise the Morse exam to 12 WPM for Amateur Extra applicants while increasing the technical level on written examinations for both classes.

END